
Southeastern Nanotechnology Infrastructure Corridor (SENIC)

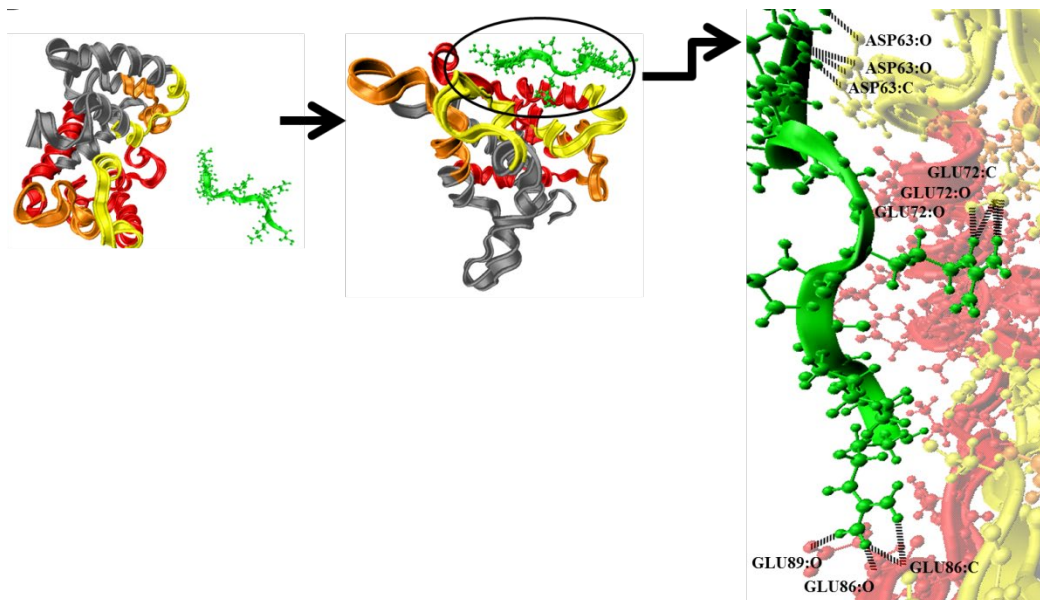
Research and Education Highlights

Year 2 (October 2016 – September 2017)



Simulations of S100B Protein with Peptide aptamers

This work highlights the design and modeling of peptide aptamers specific for S100B protein. Multiple aptamers were created in-silico for high affinity binding region (residue 62 to 73) of the S100B protein. These combinations were modeled using GROMACS in saline environment with calcium. The peptides we designed were bound to the S100B protein in the high affinity region. The average binding distance between the atoms was 1.57Å. Variation in the calcium concentration and repeat experiments show continued interaction with the high affinity binding region of the S100B Protein.



A ribbon, ball and stick representation of a molecular dynamics simulation of peptide_β (green) with the S100B protein (note the high affinity region is highlighted in yellow). The image shows snapshots on the initial and final conformations with the final binding conformation highlighted

Kristen Rhinehardt, Ram Mohan, North Carolina Agricultural and Technical State University
Work performed at the Joint School of Nanoscience and Nanoengineering

Pitch-Induced Bandgap Tuning in Self-Catalyzed GaAsSb Axial NWs using Molecular Beam Epitaxy

This work targets on the scalability and reliable performance of nanowire (NW)-based electronic device. It explored the pitch-induced effect on the geometry, absorption and band gap tuning in GaAsSb axial and core-shell (C-S) configurations, providing a new pathway for band gap engineering. The optimization of process and growth parameters result in a growth of >90% occupancy of GaAsSb axial and C-S on the patterned holes. The secondary fluxes re-emitted from the side facets of the neighboring NWs were found to contribute substantially towards the growth for smaller pitch lengths, while those from the oxide surface dominate at larger pitch lengths for high V/III beam equivalent pressure ratios. Excellent agreement between the experimental and simulated results have been observed for the pitch dependent axial and radial NW dimensions of the axial and C-S configured GaAsSb NWs.

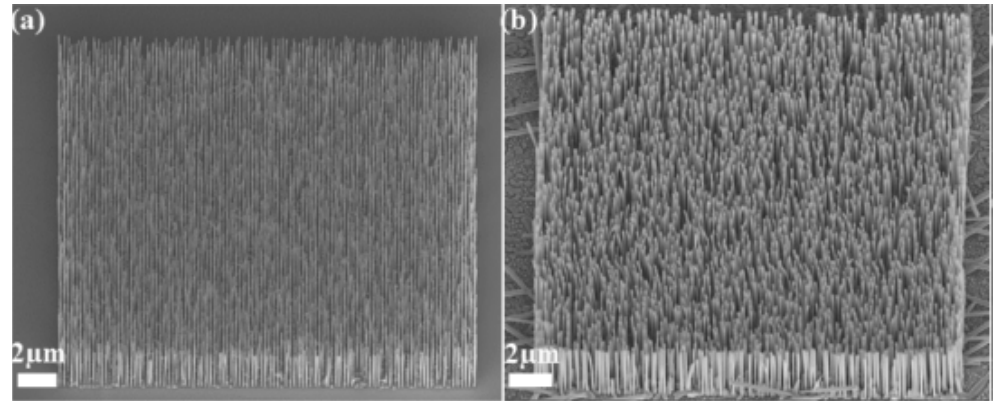


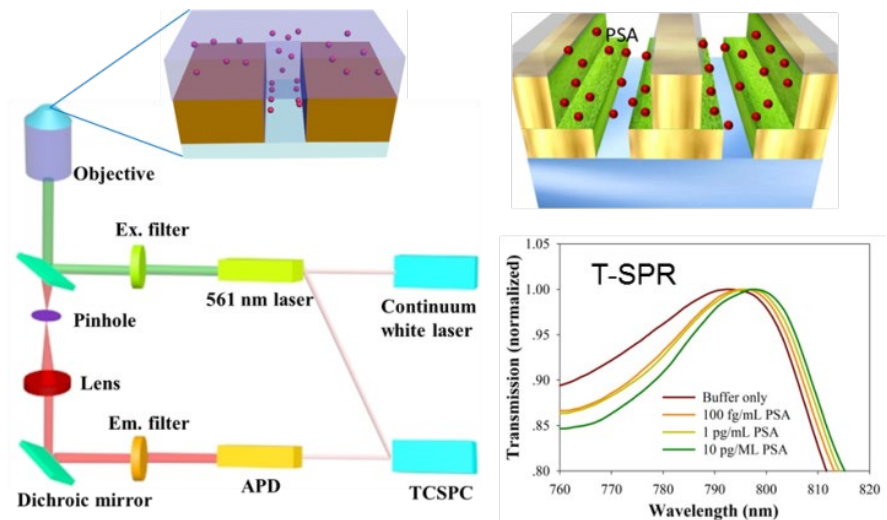
Figure 1: (a) SEM images of patterned growth of GaAsSb (a)axial and (b) core-shell NWs.

Shanthy Iyer, Manish Sharma, Pavan Kasanabonia, North Carolina A&T State University. This work is financially supported by Army Research Office and National Science Foundation.

Work performed at the Joint School of Nanoscience and Nanoengineering

Protein Trapping in Plasmonic Nanoslit and Nanoledge Cavities: The Behavior and Sensing

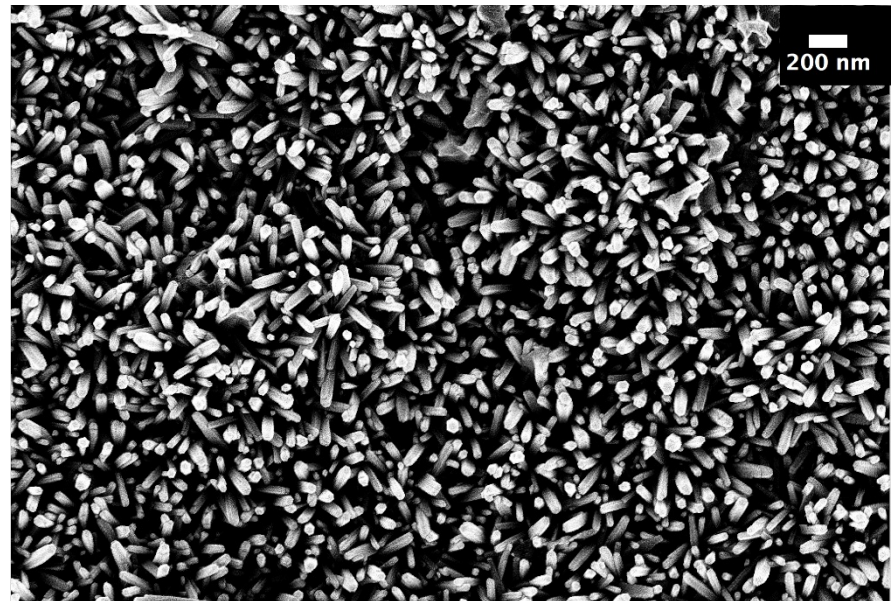
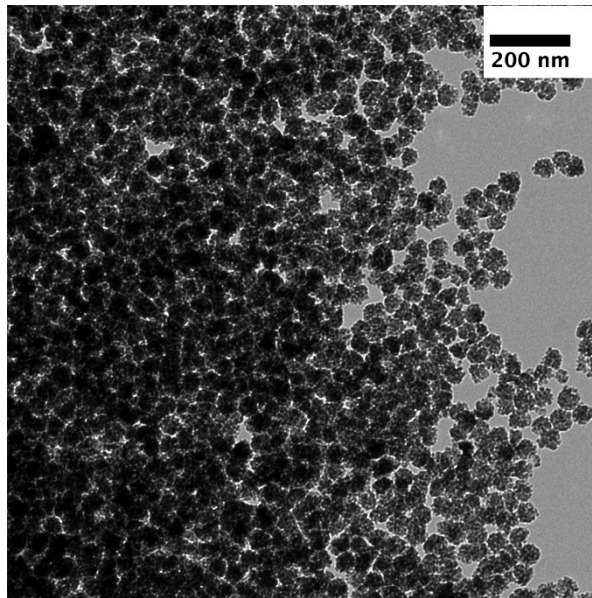
A novel plasmonic nanoledge device was presented to explore the geometry-induced trapping of nanoscale biomolecules and examine a generation of surface plasmon resonance (SPR) for plasmonic sensing. To design an optimal plasmonic device, a semianalytical model was implemented for a quantitative analysis of SPR under plane-wave illumination and a finite-difference time-domain (FDTD) simulation was used to study the optical transmission and refractive index (RI) sensitivity. In addition, total internal reflection fluorescence (TIRF) imaging was used to visualize the migration of fluorescently labeled bovine serum albumin (BSA) into the nanoslits; and fluorescence correlation spectroscopy (FCS) was further used to investigate the diffusion of BSA in the nanoslits. Transmission SPR measurements of free prostate specific antigen (f-PSA), which is similar in size to BSA, were performed to validate the trapping of the molecules via specific binding reactions in the nanoledge cavities. The present study may facilitate further development of single nanomolecule detection and new nanomicrofluidic arrays for effective detection of multiple biomarkers in clinical biofluids.



Zheng Zeng, Xiaojun Shi, Taylor Mabe, Adam W. Smith, Jianjun Wei*, *Anal. Chem.*, 2017, 89 (10), pp 5221–5229; University of North Carolina at Greensboro. Work performed at Joint School of Nanoscience and Nanoengineering

Aligned Zinc Oxide Nanorods as Interfacial Layer for Tandem Solar Cells

This work targets exploring large-scale green synthesis process to make thin films of aligned metal/metal oxide nanorods as potential interfacial layer for solar cells with tandem device architecture. Our group has developed a simple wet-aqueous based green synthesis method to make metal/metal oxide nanostructures with ordered morphology.

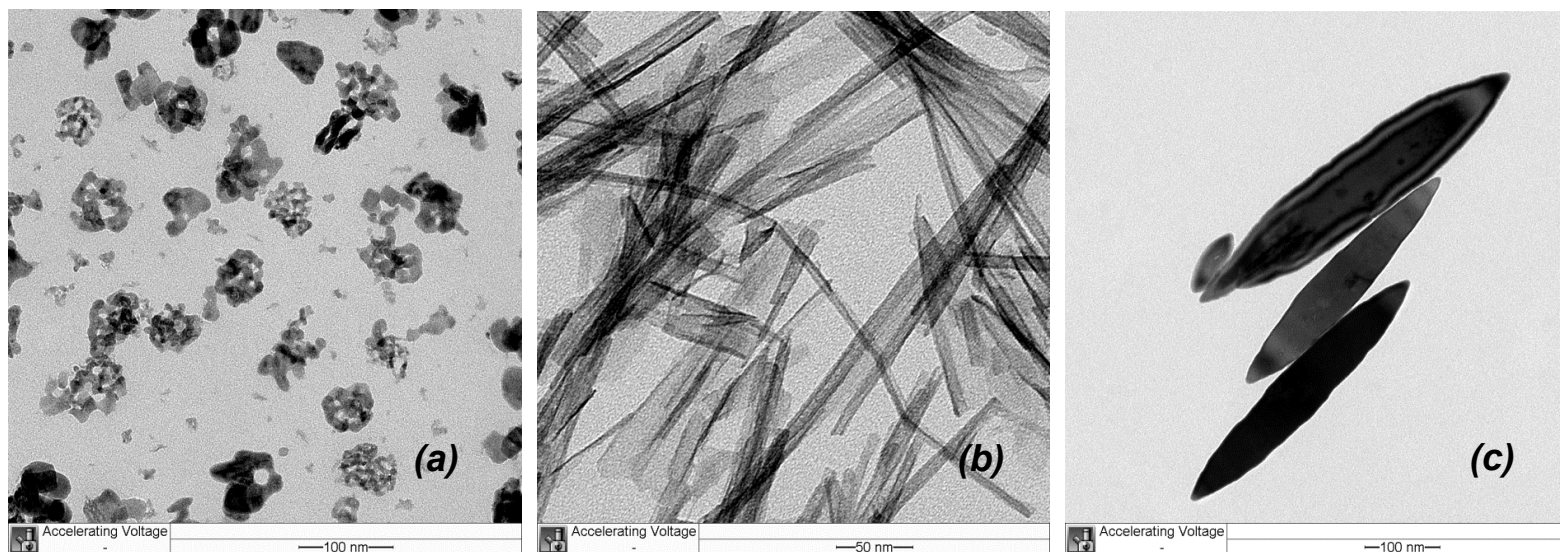


TEM image of ZnO Seeds (left) and SEM micrograph of aligned ZnO Nanorods (right) on glass substrate grew from aqueous sol-gel process.

Klinton Davis and Hemali Rathnayake, Nanoscience Department, University of North Carolina Greensboro.
Work performed at Joint School of Nanoscience and Nanoengineering

Morphology control of TiO_2 based Nanostructures

This work focuses on the morphology control of TiO_2 based nanostructures, thus tailoring the optical performance of these unique nanomaterials. TiO_2 nanoparticles are assembled to black TiO_2 nanocages, titanate nanotubes and TiO_2 nanospindles by hydrothermal processes. The morphology and composition changes in the TiO_2 structure offer distinct optical properties comparing to the spherical TiO_2 analogues.

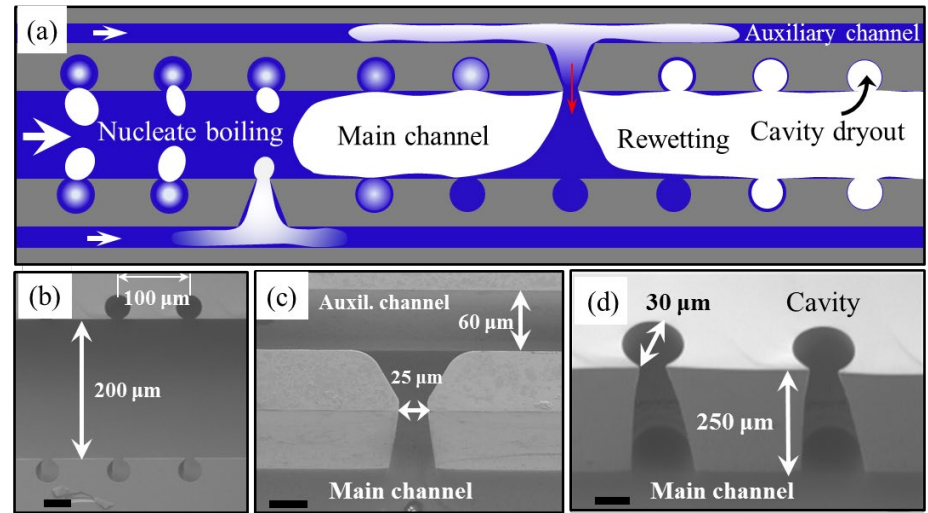


TEM micrographs of TiO_2 based nanostructures synthesized from hydrothermal process for tailoring the optical performance. (a) Black TiO_2 nanocages, (b) Titanate nanotubes, (c) TiO_2 nanospindles.

Nikita Kevlich, Sean Davis, Gordon Zhang and Bryan Koene, Luna Innovations Inc.
Work performed at Joint School of Nanoscience and Nanoengineering

Enhanced Flow Boiling in Microchannels at a Reduced Mass Velocity

In a microchannel configuration, higher mass velocity can lead to enhanced flow boiling performances, but at a cost of two-phase pressure. It is highly desirable to achieve a high heat transfer rate and critical heat flux (CHF) exceeding 1 kW/cm^2 without elevating pressure drop, particularly, at a reduced mass velocity. In this study, we developed a microchannel configuration that enables more efficient utilization of coolant through integrating multiple microscale nozzles connected to auxiliary channels as well as microscale reentry cavities on sidewalls of main microchannels, as shown in Fig. 1. Two primary enhancement mechanisms are: (a) the enhanced global liquid supply by four evenly-distributed micronozzles, particularly near outlet region, and (b) the effective management of local dryout by capillary flow-induced sustainable thin liquid film resulting from an array of microscale cavities. This project was supported by ONR under N00014-12-10724



Concept and structure of the microchannel with integrated multiple microscale nozzles and reentry cavities. (a) Improved global liquid supply to main channels through auxiliary channels via nozzles, the bubbles nucleate from nozzles and cavities, and local liquid spreading by microscale reentry cavity-induced capillary flows. (b) SEM (Scanning Electron Microscope) image of a top view of the main channel integrated with embedded reentry cavities (cavity dimensions: diameter = $30 \mu\text{m}$, opening = $6 \mu\text{m}$, distance = $100 \mu\text{m}$). (c) SEM of a micronozzle from aerial view of 45° , which connects both auxiliary and main channels. (d) SEM of two reentry cavities inside the sidewall. (All scale bars are $40 \mu\text{m}$).

Wenming Li, Fanghao Yang, and Chen Li, University of South Carolina
Work performed at GT Institute for Electronics and Nanotechnology

Submicron area resonant tunnelling diodes defined through ohmic contacts

The most common means of isolating the active area of resonant tunnelling diodes (RTDs) is through mesa etching. Such a process, especially when done with reactive ion etching, leaves space-charge regions on the sidewalls of the mesa structure. This introduces an additional current component through the RTD, degenerating the peak-to-valley current ratio (PVCR).

In literature it has been shown that the PCVR of the RTD can be preserved when scaling below submicron dimensions by a simple shallow etch, only removing material from the doped contact layers. Submicron dimensions have also been achieved through the use of Schottky contacts, although this would not preserve the symmetrical characteristic curve of the RTD.

In our work, we propose the use of annealed ohmic contacts to replace the doped contact layers of the RTD. Annealing of Germanium into semi-insulating Gallium Arsenide layers has shown a sharp change in doping concentration as the depth of the contact is examined. This sharp doping change is the key to submicron active area isolation.

A. Gaskell, T. Stander, W. E. Meyer, and H. E. Beere, Carl and Emily Fuchs Institute for Microelectronics (CEFIM), University of Pretoria, South Africa
Work performed at GT Institute for Electronics and Nanotechnology

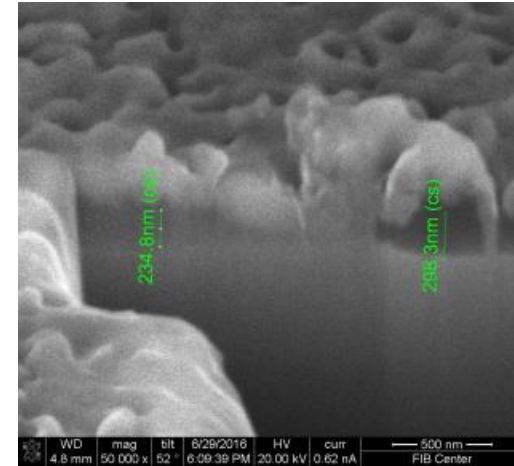


Figure 1: A SEM cross-section of a 400 nm contact hole in silicon dioxide, filled with copper to mimic the contact.

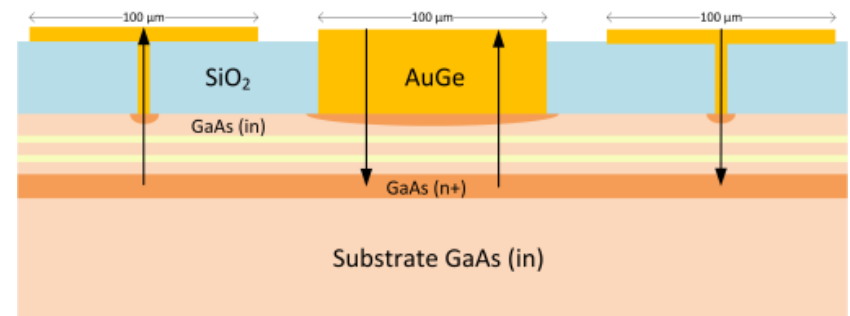
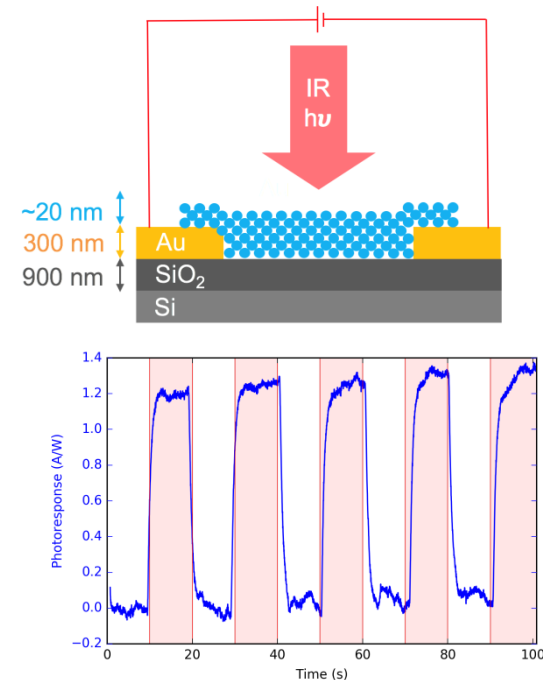


Figure 2: A schematic of a Goto latch RTD series pair created through ohmic contact fabrication.

Plasmonic ITO Nanocrystal Infrared Photodetector

Metal-insulator-metal (MIM) devices, which utilize a rectifying diode together with an infrared (IR) antenna, offer a route to convert infrared photons into electrical current. We seek to advance the design of MIM thermal radiation photodetectors and energy harvesting devices by leveraging the localized surface plasmon resonances (LSPRs) of ITO nanocrystals as deep sub-wavelength IR antennas.

A symmetric test structure was utilized for photoresponse measurements (top). Photoresponse values near 10^{-7} A/W at a bias of 1V were measured (bottom). To our knowledge, this is the first demonstration of photoresponse from infrared LSPRs. Work is on-going to improve the photodetector's design and to also explore energy harvesting devices.

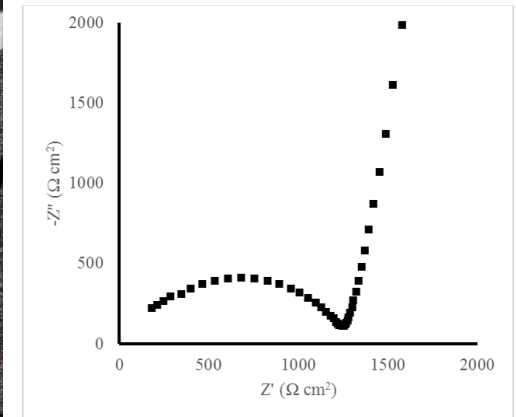
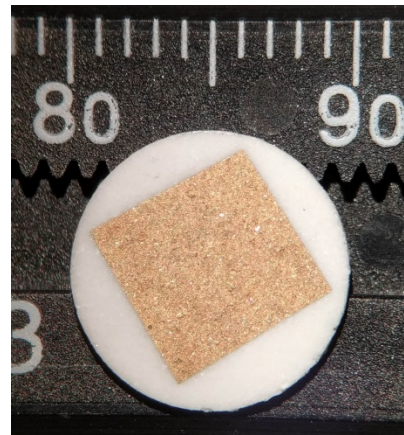


A schematic of an ITO NC film characterization platform and an IR photoresponse measurement as a function of time at bias of 1V across the NC film.

Dmitriy A, Boyuk, Weize Hu and Michael A. Filler, Georgia Institute of Technology
Work performed at Georgia Tech's Institute for Electronics and Nanotechnology (IEN
Seed Grant)

Controlling Interfaces in Ceramic Ion Conductors for Next-Generation Lithium Batteries

The goal of this work is to design, synthesize, and test new protection layers for solid-state batteries to enable long term operation of these devices. Solid-state batteries are promising energy storage systems, but instabilities at interfaces between solid electrolytes and electrodes limit performance. Here, we have fabricated different types of solid electrolyte materials, and we have used thin film deposition methods to deposit protection layers at interfaces. This project has set the stage for in situ measurement of interface reactivity and transformation processes that will provide fundamental insight into the stability of these materials.

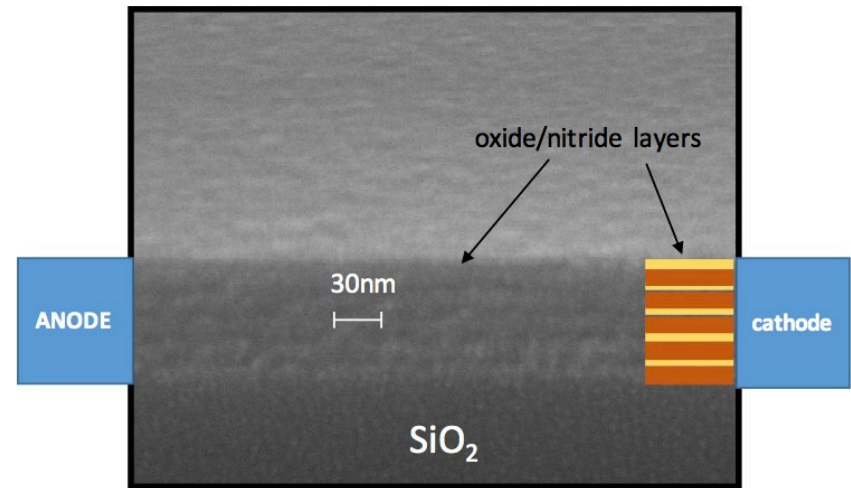


Left: Sintered solid-state electrolyte pellet with gold film as an electrical contact. Right: electrochemical impedance spectroscopy of pellet showing high ionic conductivity.

Prof. Matthew T. McDowell, Francisco Quintero Cortes, David Yeh, Georgia Institute of Technology
Work performed at Georgia Tech's Institute for Electronics and Nanotechnology (IEN Seed Grant)

Dielectric Interfacial Capacitive Energy Storage (DICES) Device Fabrication

This work is focused on optimizing fabrication methods for an experimental planar capacitor that will be used to study the electrical properties of the interfaces between nanolaminate layers of metal oxide materials (see figure). This research derives its motivation from variety of experimental studies of nanoparticle composite materials that have revealed possible anomalous polarization properties at the surface of metal-oxide nanoparticles. This new experimental test structure has been adapted to more readily and directly characterize interfacial polarization than in randomize nanoparticle structures. With thin enough laminates, this structure can possibly achieve a higher energy density than its nanoparticle equivalents.

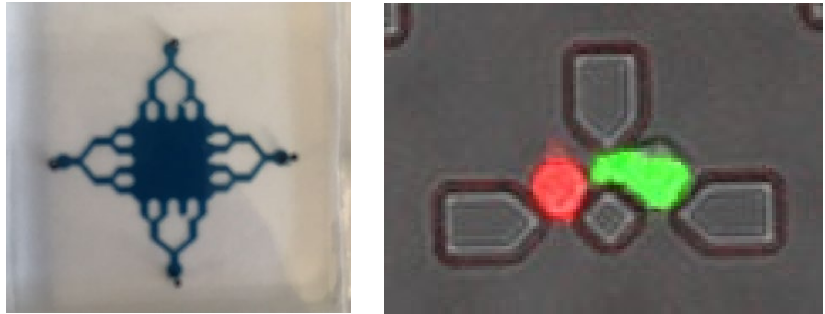


SEM micrograph nanolaminate layers to be used in a planar capacitor structure used to study the interfacial polarization properties between materials.

Blaine Costello, Zeinab Mousavi-Karimi and Jeff Davis, Georgia Institute of Technology
Work performed at Georgia Tech's Institute for Electronics and Nanotechnology (IEN Seed Grant)

Leveraging Microfabricated Systems to Investigate Direct Neutrophil-to-Neutrophil Communication

Neutrophils are a specialized subset of white blood cells crucial to the innate immune response. Upon activation, they migrate to a site of infection, engulf invading microbes, and release soluble factors to activate additional immune cells. Interestingly, recent studies have shown that as neutrophils surround a site of infection, they behave in concert and physically “merge” with each other, and then induce reprogramming in their neighboring adjacent cells, but this process is poorly understood. To study these phenomena, the Lam lab has created a microfluidic device to monitor neutrophils at a single-cell level, exploring both biological and biophysical methods of direct neutrophil-neutrophil communication in real time.



This microfluidic device consists of two paired sets of inlets and outlets surrounding a 0.5 cm by 0.5 cm capture area. Within the capture area, T-shaped traps are designed to study cell signaling. Using the paired inlets and outlets, heterotypic cell types can be placed in close proximity and communication can be monitored.

Meredith E. Fay and Wilbur A. Lam, Georgia Institute of Technology and Emory University
Work performed at Georgia Tech's Institute for Electronics and Nanotechnology

Chiral Metamaterials for Optical Modulation and Signal Processing

Metamaterials can be designed to exhibit extraordinarily strong chiral responses. We realized a set of photonic metamaterials that possess pronounced chiroptical features in the nonlinear regime. In addition to the gigantic chiral properties such as the circular dichroism and polarization rotation, the metamaterials demonstrate a distinct contrast between second harmonic responses from the two circular polarizations. These structures are further exploited for chiral-selective two-photon luminescence from quantum emitters, photon-drag effect with helicity-sensitive generation of photocurrent, and all-optical modulation of chiroptical responses under a modest level of excitation power.

This work was highlighted in a number of science media, and was featured on the homepage of the National Science Foundation.

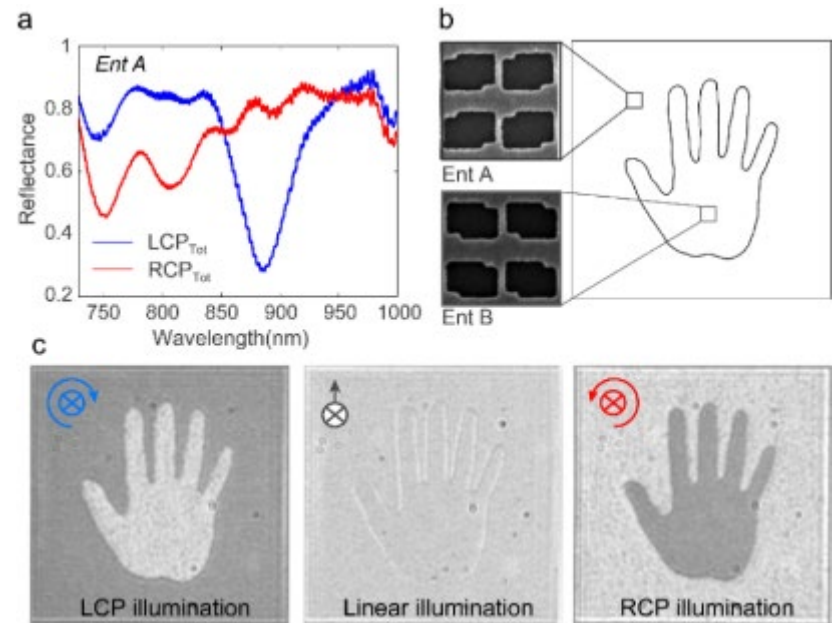


Figure. (a) Measured circular dichroism spectra of a chiral metamaterial. (b) Schematic of enantiomeric placement in the pattern. (c) Imaging of the chiral pattern under linear and circularly polarized lights.

Wenshan Cai, Georgia Institute of Technology

Work performed at Georgia Tech's Institute for Electronics and Nanotechnology

Encouraging URM's in STEM

SENIC at Georgia Tech has developed a partnership with Atlanta Public Schools' Gifted and Talented Program to encourage underrepresented students to consider STEM for education and career choices. Primarily, we place 11th and 12th grade students in faculty labs with graduate student mentors to undertake research. APS is a minority serving district (82% black; 11% white; 3% Hispanic). We host approximately four students each spring and in late April they present talks on their research experience during a capstone event at APS and also at Georgia Tech. In addition we host the APS Pipeline event for 9th and 10th grade students who APS is encouraging to participate in for their Gifted and Talented Program.



APS interns with mentors



APS Pipeline Event